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14. ABSTRACT

The Flower Garden Banks National Marine Sanctuary (FGBNMS) consists of three separate areas in the northwestern Gulf of Mexico where salt dome crests rise to within ~18-meters of the surface from an outer-continental shelf relief of 100-150-meters, and these geologic features provide a platform for unique coral reef ecosystems. It is known that such ecosystems are sensitive to photon flux variability, and this is particularly the case for Mesophotic Coral Ecosystems (MCE's) that consist of light-dependent corals growing beyond the depth limit of traditional SCUBA surveys. Thus we are combining MODIS and SeaWiFS ocean color data with atmospheric and in-water radiative transfer models, as well as high-resolution ocean circulation models, in order to establish baseline environmental conditions for FGBNMS coral reef communities - with specific emphasis on near-bottom Photosynthetically Available Radiation (PAR). Since the original FGBNMS boundary designation in January 1992, high-resolution multibeam bathymetry surveys have revealed numerous other topographic features in the surrounding region capable of supporting biological communities designated by the FGBNMS managers as critical habitats. It is an additional aim of this research to identify likely locations for specific biological communities where no detailed surveys have been performed.

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Establishing Baseline Subsurface Light Fields for the Flower Garden Banks National Marine Sanctuary

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ABSTRACT

The Flower Garden Banks National Marine Sanctuary (FGBNMS) consists of three separate areas in the northwestern Gulf of Mexico where salt dome crests rise to within ~18-meters of the surface from an outer-continental shelf relief of 100-150-meters, and these geologic features provide a platform for unique coral reef ecosystems. It is known that such ecosystems are sensitive to photon flux variability, and this is particularly the case for Mesophotic Coral Ecosystems (MCE's) that consist of light-dependent corals growing beyond the depth limit of traditional SCUBA surveys. Thus we are combining MODIS and SeaWiFS ocean color data with atmospheric and in-water radiative transfer models, as well as high-resolution ocean circulation models, in order to establish baseline environmental conditions for FGBNMS coral reef communities – with specific emphasis on near-bottom Photosynthetically Available Radiation (PAR). Since the original FGBNMS boundary designation in January 1992, high-resolution multibeam bathymetry surveys have revealed numerous other topographic features in the surrounding region capable of supporting biological communities designated by the FGBNMS managers as critical habitats. It is an additional aim of this research to identify likely locations for specific biological communities where no detailed surveys have been performed.

METHODS

The essential task of this project is to combine satellite data with ocean models in order to establish baseline environmental conditions for coastal and shelf marine habitats and to communicate this information to decision-makers and environmental resource managers. Accordingly, our first step is to establish a nested ocean model hierarchy for the Gulf of Mexico in order to provide background and high-resolution blended model/data products to the end-user. We have completed our nested model setup using the Navy Coastal Ocean Model (NCOM) and we are currently executing model runs. The nested configuration for the Flower Garden Banks National Marine Sanctuary (FGBNMS) presently consists of three nests: 1) the ~9 km horizontal resolution regional Gulf of Mexico Modeling System (GOMMS; deRada et al., 2009), which receives boundary information from the operational Global NCOM system (Kara et al., 2006; http://www7320.nrlssc.navy.mil/global_ncom/); a nested domain for the outer Louisiana-Texas continental shelf at ~2 km horizontal resolution; and a very high-resolution (250-meter) domain that encompasses the East/West Flower Garden Banks as well as numerous other banks of interest to decision-makers. Multibeam sonar bathymetry (Gardner et al., 1998) at 5-meter resolution has been assimilated into the 250-meter resolution model domain. Additional bathymetry data on new features near the FGBNMS has been provided by NOAA's National Coastal Data Development Center (NCDDC).

As a reference and benchmark for the nested model configurations, we have constructed a preliminary temperature climatology for the FGBNMS using the Modular Ocean Data Assimilation System (MODAS; Fox et al., 2002). MODAS is a blend of satellite altimetry/temperature data sets and multivariate optimal interpolation algorithms that project sea surface temperatures down into the water column to create a synthetic three-dimensional temperature field. Daily MODAS synthetics were averaged (2002-2005) to create seasonal bottom temperatures. The caveat to these preliminary results is that the MODAS is coarser in horizontal resolution (~2-4 km) than what is required for the FGBNMS where each topographic feature is on the order of ~10 km in horizontal scale and biological community scales are on the order of meters. Results from the very high resolution nested NCOM model will demonstrate where the coarse resolution hindcasts interpolated to finer scales are failing to provide adequate information.

In addition, we have begun implementing light propagation models for the atmosphere and upper ocean in order to provide estimates of near-bottom Photosynthetically Available Radiation (PAR). Near-bottom PAR flux is an environmental variable needed to assess the status of hermatypic coral, coralline algae, and mesophotic coral reef ecosystems within the FGBNMS and in similar areas throughout the northern Gulf of Mexico. An annual near-bottom photon flux climatology has been constructed based on a clear-sky atmospheric transmission model (Gregg and Carder, 1990; Gregg and Casey, 2009).

For the propagation of light through the ocean's surface layers, we employ the broadband PAR attenuation scheme of Lee et al. (2005), which has been used successfully in ecosystem models (*see* Penta et al., 2008). The input required is an estimate of the total absorption coefficient (*a* – 490 nm) and the total backscattering coefficient (*bb* - 490 nm) at the ocean's surface. Preliminary surface time series for these variables have been constructed from a 2002-2005 LAC SeaWiFS dataset as processed and archived at the Naval Research Laboratory, Stennis Space Center. The data are processed using an Inherent Optical Property (IOP) retrieval algorithm (Lee et al., 2002). The SeaWiFS IOP values are used in a daily photon flux simulation that presently accounts for hourly variation in sun angle, and is currently being modified to account for other sources of variability in the ocean (sea state, for example) and the atmosphere. The photon fluxes for each depth are averaged in time to arrive at a mean annual photon flux for the benthos.

RESULTS

Seasonal mean MODAS water column temperatures are scaled up to 5-meter resolution for the West Flower Garden Bank (Figure 1). The 28-meter annual temperature range is ~20.0 to 26.5 °C and peaks in late August/early September, a seasonal cycle consistent with the mean basin-wide SST signal estimated from satellites (Jolliff et al., 2008). Similar bottom temperature products are constructed for other banks and identified features of interest near the FGBNMS. Of these, Jakkula Bank (~270 km east of the West Flower Garden Bank) July-August-September (JAS) mean bottom temperatures are ~ 0.5 - 1 °C warmer on the 100-meter isobath than those of WFGB. For many of the banks, the strong seasonal cycle evident in the satellite SST is greatly diminished by ~80 meters depth.

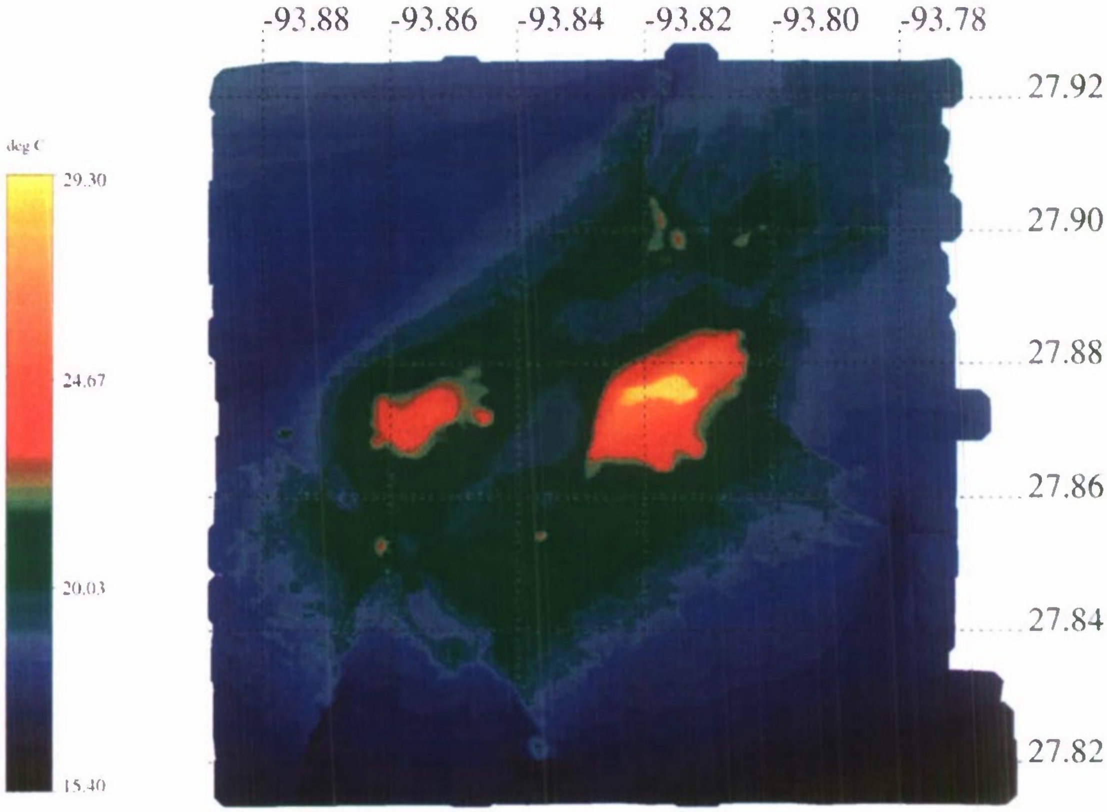

Figure 1. MODAS-resolved July-August-September mean bottom temperatures over the West Flower Garden Banks.

These scaled down temperature products are compared here to *in situ* temperature probe data from the Flower Garden Banks Long Term Monitoring Report 2002-2003 (Precht et al., 2006). The 2002-2003 MODAS reef cap product is consistent with the HoboTemp thermograph records (r = 0.94; RMSD = 1.26 °C; Figure 2a) and the YSI 6600 series datasonde temperature record (r= 0.93; RMSD = 1.12 °C; Figure 2b).

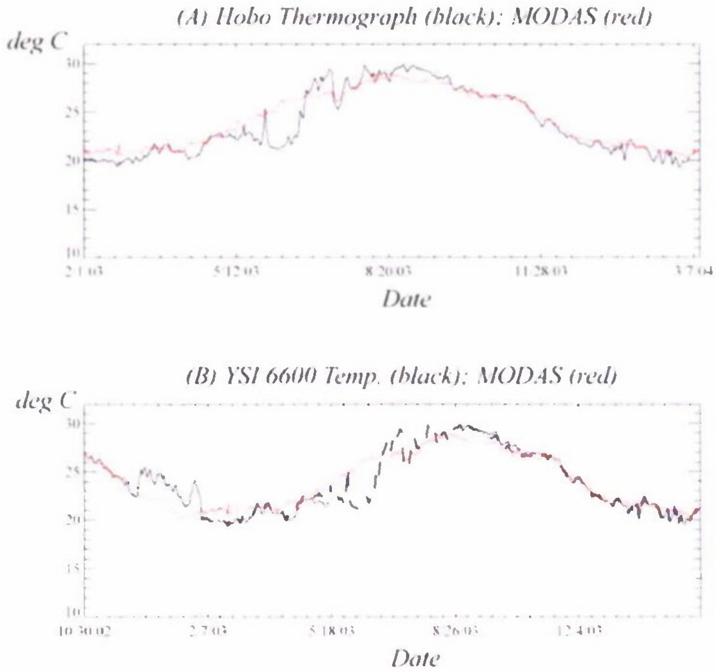

Figure 2. Comparison of in situ temperature records of the West Flower Garden Bank and the MODAS-resolved bottom temperature.

Mean bottom PAR fields are also created for the West Flower Garden Bank with the satellite data, clear sky irradiance model, and the PAR penetration scheme (Figure 3). Validation of the subsurface light field from time series concomitant with temperature is much more difficult due to paucity of data. The YSI 6600 PAR sensor deployed on the West Flower Garden Bank in 2002-2003 did not record data for much of the period record and the data recovered exhibit a large amount of high-frequency variability, likely due to clouds. Further work will more rigorously address the cloud signal in these data and products. Presently, the clear sky values are selected as an upper-limit to the subsurface estimates so that we may estimate the maximum estimated depth where mesophotic coral ecosystems may be detected.

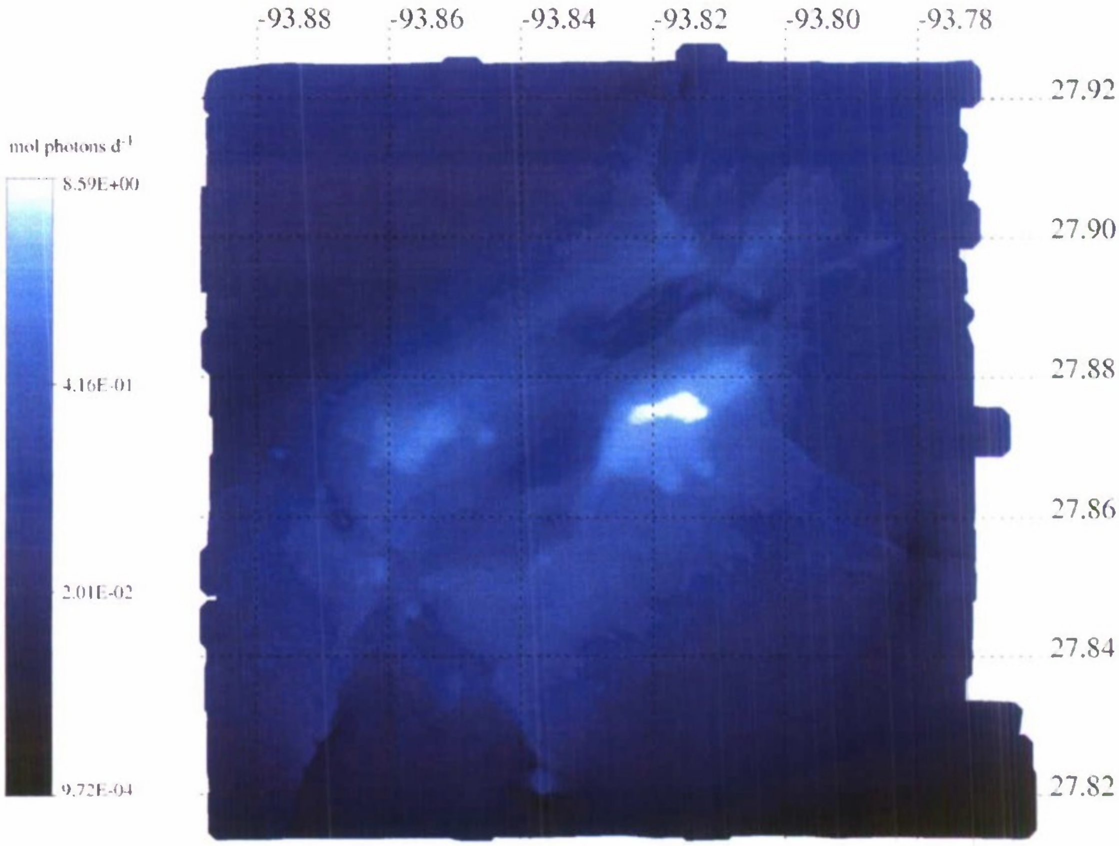

Figure 3. Mean annual bottom PAR flux (mol photons d^{-1}) for the West Flower Garden Bank high-resolution bathymetry.

The clear sky surface irradiance computations are not significantly different over the varying sites (but this may change when additional sources of variability are accounted for in the simulations). Nonetheless, we may calculate the total area of benthic habitat falling within various photic zones defined by the mean SeaWiFS IOP products and the high-resolution bathymetry. We define these zones based on the satellite IOP estimate of the diffuse downwelling attenuation coefficient (kd-490 nm), calculated as 1.33(*a*-490 + *bb*-490), as follows:

(1) total area (km^2) < 2.3/kd-490
(2) 2.3 / kd-490 ≤ total area (km^2) < 4.6/kd-490
(3) 4.6 / kd-490 ≤ total area (km^2) < 6.9/kd-490

Zone (3) is between the 1% and 0.1% penetration depth at 490 nm and is not normally considered in biological oceanographic studies of primary productivity. Photon penetration to this depth range would be nominal. The results are presented in Table 1 and show that ~75 % of the resolved high-resolution bathymetry receiving nominal sunlight exists in the "twilight zone" (zone 3), or approximately 86-130-meters depth given the overall spatial/temporal homogeneity of the retrieved satellite IOP's for this region. Sonnier and Stetson Banks would be the exception to these values, likely owing to their position closer to the coast. The twilight zone depth range for those features is ~71 – 106 meters. Most of the remaining fraction of benthic habitat exists in the 1-10% 490 nm range, or ~43 to 86 meters for most of the banks examined. For the sun at zenith and a clear sky, we estimate a bottom PAR flux of < 4.6 μEin m^{-2} s^{-1} over this depth range. MODAS-resolved seasonally averaged bottom temperatures in this depth range are generally between ~20 – 25 °C. It is interesting to note that the 1% 490 nm depth is approximately where the subsurface MODAS-resolved temperature ceases to be coherent with the seasonal SST cycle. Thus, zones 2 and 3 are very different with respect to light and temperature.

Table 1. Photic Zone distribution of FGBNMS-area features resolved by high-resolution bathymetry.

Table 1. Banks	**Zone 1 (km^2)**	**Zone 2**	**Zone 3**
Alderdice	0.0	4.3	127.2
Bright and Rankin	0.0	22.4	176.4
East FGB	3.0	28.3	78.3
Geyer	0.0	19.3	9.9
Jakkula	0.0	1.9	45.2
MacNeil/29 Fathom	0.0	84.1	221.0
McGrail Bouma Rezak Sidner	0.0	74.2	421.8
Stetson	0.1	11.8	0.0
West FGB	1.3	31.4	88.0
Sonnier	0.1	93.8	0.0
Totals	4.5	371.5	1167.8
(%)	0.3	24.1	75.6

DISCUSSION

The coral reef cap communities of the East and West Flower Garden Banks have been well-surveyed and remain under the protection and monitoring of the National Marine Sanctuary system. Our calculations demonstrate, however, that from an optical/photic-depth point-of-view these habitats are an exceedingly small fraction of the total benthic habitat available in the area. The larger ecological question remains: how are these various habitats connected? Or rather, how do the much larger deeper habitats function in ways that support and maintain the reef cap communities? During times of environmental stress, MCE's in the deeper benthic habitats may serve as deep water refugia for a wide range of species often observed in the reef cap areas (Kahng et al., 2010). Unfortunately, finding, surveying, and studying these deep water habitats is expensive and time consuming. It is our aim, therefore, to provide products that may aid in biological survey mission planning and the potential identification of critical habitats in the Flower Garden Banks region.

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